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TECHNICAL MANUAL FOR THE MEASUREMENT OF FUGITIVE EMISSIONS: ROOF MONITOR SAMPLING METHOD FOR INDUSTRIAL FUGITIVE EMISSIONS

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16. ABSTRACT The technical manual presents fundamental considerations that are required in using the Roof Monitor Sampling Method to measure fugitive emissions. Criteria for selecting the most applicable measurement method and discussions of general information gathering and planning activities are presented. Roof Monitor sampling strategies and equipment are described, and sampling system design, sampling techniques, and data reduction are discussed. Manpower requirements and time estimates for typical applications of the method are presented for programs designed for overall and specific emissions measurements. The application of the outlined procedures to the measurement of fugitive emissions from an electric-arc furnace steelmaking plant is presented as an appendix.

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TECHNICAL MANUAL FOR THE MEASUREMENT OF FUGITIVE EMISSIONS: QUASI-STACK SAMPLING METHOD FOR INDUSTRIAL FUGITIVE EMISSIONS

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1.0 OBJECTIVE

The objective of this technical manual is to present a guide for the utilization of the Roof Monitor Sampling Method in the measurement of fugitive emissions. Criteria for the selection of the most applicable measurement method and discussions of general information gathering and planning activities are presented. Roof Monitor sampling strategies and equipment are described and sampling system design, sampling techniques, and data reduction are discussed.

Manpower requirements and time estimates for typical applications of the method are presented for programs designed for overall and specific emissions measurements.

The application of the outlined procedures to the measurement of fugitive emissions from an electric arc furnace steel making plant is presented as an appendix.

2.0 INTRODUCTION

Pollutants emitted into the ambient air from an industrial plant or other site generally fall into one of two types. The first type is released into the air through stacks or similar devices designed to direct and control the flow of the emissions. These emissions may be readily measured by universally-recognized standard stack sampling techniques. The second type is released into the air without control of flow or direction. These fugitive emissions usually cannot be measured using existing standard techniques.

The development of reliable, generally applicable measurement procedures is a necessary prerequisite to the development of strategies for the control of fugitive emissions. This document describes some procedures for the measurement of fugitive emissions using the roof monitor measurement method described in Section 2.1.3 below.

2.1 Categories of Fugitive Emissions

Fugitive emissions emanate from such a wide variety of circumstances that it is not particularly meaningful to attempt to categorize them either in terms of the processes or mechanisms that generate them or the geometry of the emission points. A more useful approach is to categorize fugitive emissions in terms of the methods for their measurement. Three basic methods exist--quasi-stack sampling, roof monitor sampling, and upwind-downwind sampling. Each is described in general terms below.

2.1.1 Quasi-stack Sampling Method

In this method, the fugitive emissions are captured in a temporarily installed hood or enclosure and vented to an exhaust duct or stack of

regular cross-sectional area. Emissions are then measured in the exhaust duct using standard stack sampling or similar well recognized methods. This approach is necessarily restricted to those sources of emissions that are isolable and physically arranged so as to permit the installation of a temporary hood or enclosure that will not interfere with plant operations or alter the character of the process or the emissions.

2.1.2 Upwind-Downwind Sampling Method

This method is utilized to measure the fugitive emissions from sources typically covering large areas that cannot be temporarily hooded and are not enclosed in a structure allowing the use of the roof monitor method. Such sources include material handling and storage operations, waste dumps, and industrial processes in which the emissions are spread over large areas or are periodic in nature.

The upwind-downwind method quantifies the emissions from such sources as the difference between the pollutant concentrations measured in the ambient air approaching (upwind) and leaving (downwind) the source site. It may also be utilized in combination with mathematical models and tracer tests to define the contributions to total measured emissions of specific sources among a group of sources.

2.1.3 Roof Monitor Sampling Method

This method is used to measure the fugitive emissions entering the ambient air from building or other enclosure openings such as roof monitors, doors, and windows from enclosed sources too numerous or un-

wieldy to permit the installation of temporary hooding. Sampling is, in general, limited to a mixture of all uncontrolled emission sources within the enclosure and requires the ability to make low air velocity measurements and mass balances of small quantities of materials across the surfaces of the openings.

These features are embodied in the typical industrial sources and their emitted pollutants contained in Table 2-1.

The roof monitor method quantifies the emissions from such sources as the average mass flux of emissions from buildings or enclosure openings over the time period of measurement. The flux is obtained from air and pollutant material balances across the openings. Tracer tests may also be used in combination with it to define the contributions of individual sources.

2.2 Selection of Sampling Method

The initial step in the measurement and documentation of fugitive emissions at an industrial site is the selection of the sampling method to be employed. Although it is impossible to emunerate all the combinations of influencing factors that might be encountered in a specific situation, careful consideration of the following general criteria should result in the selection of the most effective sampling method.

2.2.1 Selection Criteria

The selection criteria listed below are grouped into three general classifications common to all fugitive emissions measurement methods. The criteria are intended to provide only representative examples and should not be considered a complete listing of influencing factors.

TABLE 2-1

TYPICAL INDUSTRIAL FUGITIVE EMISSIONS SOURCES
MEASURED BY THE ROOF MONITOR SAMPLING METHOD

Industry	Source	Particulate Emissions	Gas and Vapor Emissions
Iron & Steel Foundries	Furnace or Cupola Charging	Fume, Carbon Dust, Smoke (Oil)	CO, HC, SO_2
	Melting	Fume, Dust	CO, SO_2
	Mold Pouring	Dust	CO, HC, PNA, Odor
Electric Furnace Steel	Charging	Metallic Fumes, Carbon Dust	CO
	General Operations	Metallic Fumes, Dust	CO
Primary Aluminum	Carbon Plant	Tars, Carbon Dust	CO, HC, SO_2
	Potroom	Tars, Carbon & Aluminum Dust, Flourides	CO, HC, SO_2, HF
	Alumina Calcining	Alumina Dust	-
	Cryolite Recovery	Carbon & Alumina Dust, Flourides	-
Primary Copper	Converter House	Fume, Silica	SO_2
	Reverberatory Furnace	Fume	SO_2
	Roaster Operations	Fume	SO_2
Tires & Rubber	Curing Press Room	Organic Particulate	HC, Odor
	Cement House	Dust	HC, Odor
Phosphate Fertilizer	General Ventilation	Dust, Flourides	SO_2, HF
Lime	General Ventilation	Dust	-
Primary Steel	Blast Furnace Cast House	Metallic Fumes	CO, H_2S, SO_2
	BOF Operations	Metallic Fumes, Carbon Dust	CO
	Open Hearth Operations	Metallic Fumes	CO
Graphite, and Carbide Production	Arc Furnace Operation	Carbon Dust, Silica Fume	CO, Odor

2.2.1.1 Site Criteria

Source Isolability. Can the emissions be measured separately from emissions from other sources? Can the source be enclosed?

Source Location. Is the source indoors or out? Does location permit access of measuring equipment?

Meteorological Conditions. Will wind conditions or precipitation interfere with measurements? Will rain or snow on ground effect dust levels?

2.2.1.2 Process Criteria

Number and Size of Sources. Are emissions from a single, well defined location or many scattered locations? Is source small enough to hood?

Homogeneity of Emissions. Are emissions the same type everywhere at the site? Are reactive effects between different emissions involved?

Continuity of Process. Will emissions be produced long enough to obtain meaningful samples?

Effects of Measurements. Will installation of measuring equipment alter the process or the emissions? Will measurements interfere with production?

2.2.1.3 Pollutant Criteria

Nature of Emissions. Are measurements of particles, gases, liquids required? Are emissions hazardous?

Emission Generation Rate. Are enough emissions produced to provide measurable samples in reasonable sampling time?

Emission Dilution. Will transport air reduce emission concentration below measurable levels?

2.2.2 Criteria Application

The application of the selection criteria listed in Section 2.2.1 to each of the fugitive emissions measurement methods defined in Section 2.1 is described in general terms in this Section.

2.2.2.1 Quasi-stack Method

Effective use of the quasi-stack method requires that the source of emissions be isolable and that an enclosure can be installed capable of capturing emissions without interference with plant operations. The location of the source alone is not normally a factor. Meteorological conditions usually need be considered only if they directly affect the sampling.

The quasi-stack method is usually restricted to a single source and must be limited to two or three small sources that can be effectively enclosed to duct their total emissions to a single sampling point. The process may be cyclic in nature if any one cycle is of sufficient duration to provide a representative sample. The possible effects of the measurement on the process or emissions is of special significance in this method. In many cases, enclosing a portion of a process in order to capture its emissions can alter that portion of the process by changing its temperature profile or affecting flow rates. Emission may be similarly altered by reaction with components of the ambient air drawn into the sampling ducts. While these effects are not necessarily limiting in the selection of the method, they must be considered in designing the test program and could influence the method selection by increasing complexity and costs.

The quasi-stack method is useful for virtually all types of emissions and is least affected by the emission generation rate of the process. Dilution of the pollutants of concern is of little consequence since it can usually be controlled in the design of the sampling system.

2.2.2.2 Roof Monitor Method

Practical utilization of the roof monitor method demands that the source of emissions be enclosed in a structure with a limited number of openings to the atmosphere. Measurements may usually be made only of the total of all emissions sources within the structure. Meteorological conditions normally need not be considered in selecting this method.

The number of sources and the mixture of emissions is relatively unimportant since the measurements usually include only the total emissions. The processes involved may be discontinuous as long as a representative combination of the worst grouping may be included in a sampling. Measurements will normally have no effect on the processes or emissions.

The roof monitor method, usually dependent on or at least influenced by gravity in the transmission of emissions, may not be useful for the measurement of larger particulates and heavy gases which may settle within the enclosure being sampled. Emissions generation rates must be high enough to provide pollutant concentrations of measurable magnitude after dilution in the enclosed volume of the structure.

2.2.2.3 Upwind-Downwind Method

The upwind-downwind method, generally utilized where neither of the other methods may be successfully employed, is not influenced by the number or location of the emission sources except as they influence the locating of sampling devices. In most cases, only the total contribution to the ambient atmosphere of all sources within a sampling area may be measured. The method is strongly influenced by meteorological conditions, requiring a wind consistent in direction and velocity throughout the sampling period as well as conditions of temper-

ature, humidity and ground moisture representative of normal ambient conditions.

The emissions measured by the upwind-downwind method may be the total contribution from a single source or from a mixture of many sources in a large area. Continuity of the emissions is generally of little consequence since the magnitude of the ambient air volume concerned is large enough to provide a smoothing effect to any circle emissions. The measurements have no effect on the emissions or processes involved.

Most airborne pollutants can be measured by the upwind-downwind method. Generation rates must be high enough to provide measurable concentrations at the sampling locations after dilution with the ambient air. Settling rates of the larger particulates require that the sampling system be carefully designed to ensure that a representative pollutant cloud is included.

2.3 Sampling Strategies

Fugitive emissions measurements may, in general, be separated into two classes or levels depending upon the degree of accuracy desired. Survey measurement systems are designed to screen emissions and to provide gross measurements of a number of process influents and effluents; detailed systems are designed to isolate, identify accurately, and quantify individual contaminant constituents.

2.3.1 Survey Measurement Systems

Survey measurement systems employ recognized standard or state-of-the-art measurement techniques to screen the total emissions from a site or source and determine whether any of the emission constituents

should be considered for more detailed investigation. They generally utilize the simplest available arrangement of instrumentation and procedures in a relatively brief sampling program, usually without provisions for sample replication, to provide order-of-magnitude type data, embodying a factor of 2 to 5 in accuracy range with respect to actual emissions.

2.3.2 Detailed Measurement Systems

Detailed measurement systems are used in instances where survey measurements or equivalent data indicate that a specific emission constituent may be present in a concentration worthy of concern. Detailed systems provide more precise identification and quantification of specific constituents by utilizing the latest state-of-the-art measurement instrumentation and procedures in carefully designed sampling programs. Detailed systems are also utilized to provide emission data over a range of process operating conditions or ambient meteorological influences. Basic accuracy of detailed measurements is in the order of $\pm$ 10 to $\pm$ 50 percent of actual emissions.

30. TEST STRATEGIES

This section describes the approaches that may be taken to successfully complete a testing program utilizing the roof monitor sampling method described in Section 2.1. It details the information required to plan the program, describes the organization of the test plan, specifies the types of sampling equipment to be used, establishes criteria for the sampling system design, and outlines basic data reduction methods.

3.1 Pretest Survey

After the measurement method to be utilized in documenting the fugitive emissions at a particular site has been established using the criteria of Section 2.2, a pretest survey of the site should be conducted by the program planners. The pretest survey should result in an informal, internal report containing all the information necessary for the preparation of a test plan and the design of the sampling system by the testing organization.

This section provides guidelines for conducting a pretest survey and preparing a pretest survey report.

3.1.1 Information to be Obtained

In order to design a system effectively and plan for the on-site sampling of fugitive emissions, a good general knowledge is required of the plant layout, process chemistry and flow, surrounding environment, and prevailing meteorological conditions. Particular characteristics of the site relative to the needs of the owner, the products involved, the space and manpower skills available, emission control equipment in-

stalled, and the safety and health procedures observed, will also influence the sampling system design and plan. Work flow patterns and schedules that may result in periodic changes in the nature or quantity of emissions or that indicate periods for the most effective and least disruptive sampling must also be considered. Most of this information can only be obtained by a survey at the site. Table 3-1 outlines some of the specific information to be obtained. Additional information will be suggested by considerations of the particular on-site situation.

3.1.2 Report Organization

The informal, internal pretest survey report must contain all the pertinent information gathered during and prior to the site study. A summary of all communications relative to the test program should be included in the report along with detailed descriptions of the plant layout, process, and operations as outlined in Table 3-1. The report should also incorporate drawings, diagrams, maps, photographs, meteorological records, and literature references that will be helpful in planning the test program.

3.2 Test Plan

3.2.1 Purpose of a Test Plan

Measurement programs are very demanding in terms of the scheduling and completion of many preparatory tasks, observations at sometimes widely separated locations, instrument checks to verify measurement validity, etc. It is therefore essential that all of the experiment design and planning be done prior to the start of the measurement program

TABLE 3-1

PRE-TEST SURVEY INFORMATION TO BE OBTAINED
FOR APPLICATION OF FUGITIVE EMISSION SAMPLING METHODS

Plant Layout	Drawings: Building Layout and Plan View of Potential Study Areas Building Side Elevations to Identify Obstructions and Structure Available to Support Test Setup Work Flow Diagrams Locations of Suitable Sampling Sites Physical Layout Measurements to Supplement Drawings Work Space Required at Potential Sampling Sites
Process	Process Flow Diagram with Fugitive Emission Points Identified General Description of Process Chemistry General Description of Process Operations Including Initial Estimate of Fugitive Emissions Drawings of Equipment or Segments of Processes Where Fugitive Emissions are to be Measured Photographs (if permitted) of Process Area Where Fugitive Emissions are to be Measured Names, Extensions, Locations of Process Foremen and Supervisors Where Tests are to be Conducted
Operations	Location of Available Services (Power Outlets, Maintenance and Plant Engineering Personnel, Laboratories, etc.) Local Vendors Who Can Fabricate and Supply Test System Components Shift Schedules Location of Operations Records (combine with process operation information) Health and Safety Considerations
Other	Access Routes to the Areas Where Test Equipment/Instrumentation Will Be Located Names, Extensions, Locations of Plant Security and Safety Supervisors Regional Meteorological Summaries

in the form of a detailed test plan. The preparation of such a plan enables the investigator to "pre-think" effectively and cross-check all of the details of the design and operation of a measurement program prior to the commitment of manpower and resources. The plan then also serves as the guide for the actual performance of the work. The test plan provides a formal specification of the equipment and procedures required to satisfy the objectives of the measurement program. It is based on the information collected in the informal pretest survey report and describes the most effective sampling equipment, procedures, and timetables consistent with the program objectives and site characteristics.

3.2.2 Test Plan Organization

The test plan should contain specific information in each of the topical areas indicated below:

Background

The introductory paragraph containing the pertinent information leading to the need to conduct the measurement program and a short description of the information required to answer that need.

Objective

A concise statement of the problem addressed by the test program and a brief description of the program's planned method for its solution.

Approach

A description of the measurement scheme and data reduction methodology employed in the program with a discussion of how each will answer the needs identified in the background statement.

Instrumentation/Equipment/Facilities

A description of the instrumentation arrays to be used to collect the samples and meteorological data identified in the approach description. The number and frequency of samples to be taken and the sampling array resolution should be described.

A detailed description of the equipment to be employed and its purpose.

A description of the facilities required to operate the measurement program, including work space, electrical power, support from plant personnel, special construction, etc.

Schedule

A detailed chronology of a typical set of measurements, or a test, and the overall schedule of events from the planning stage through the completion ofthe test program report.

Limitations

A definition of the conditions under which the measurement project is to be conducted. If, for example, successful tests can be conducted only during occurrences of certain source operations, those favorable limits should be stated.

Analysis Method

A description of the methods which will be used to analyze the samples collected and the resultant data, e.g., statistical or case analysis, and critical aspects of that method.

Report Requirements

A draft outline of the report on the analysis of the data to be collected along with definitions indicating the purpose of the report and the audience it is to be directed to.

Quality Assurance

The test plan should address itself to the development of a quality assurance program as outlined in Section 3.7. This QA program should be an integral part of the measurement program and be incorporated as a portion of the test plan either directly or by reference.

Responsibilities

A list of persons who are responsible for each phase of the measurement program, as defined in the schedule, both for the testing organization and for the plant site.

3.3 Roof Monitor Sampling Strategies

The roof monitor sampling method, as described in Section 2.1.3, is used to quantify emissions released into the internal atmosphere of the buildings or enclosures that contain the process equipment and which are then ventilated to the external atmosphere as fugitive emissions. The roof monitor sampling method may be utilized to measure the fugitive emissions from almost any process that ventilates through building openings such as doors, windows, or any of a wide variety of roof ventilators, where the ventilation is either gravity dependent or fan driven.

The measurements made include that of the gas flow through the opening either by direct measurement or by calculation (of the gas velocity) from physical parameters (pressure drop, thermal conductivity), the cross-sectional area of the opening, and the particulate and gaseous emission concentrations in the flowing gas. These measurements or calculations provide the data necessary to determine the total flux of the fugitive emissions from all sources operating within the enclosure or from selected sources, depending on processing sequences or cycles. Since ventilation rates, especially when gravity driven, can vary, the mass emission rates so measured are averages over the emission concentration and velocity measurement period. (Sections 3.4 and 3.5 describe the equipment used for sampling, the criteria for sampling system design, sampling techniques, and data reduction procedures for respectively, survey and detailed roof monitor sampling programs).

3.4 Survey Roof Monitor Sampling Strategy

A survey measurement system, as defined in Section 2.3, is designed to provide gross measurements of emissions to determine whether any

constituents should be considered for more detailed investigations. A survey roof monitor measurement system in its simplest form utilizes one or two hi-vol type samplers set up to sample the openings by which the fugitive emissions exit the building or enclosure and an equal number of hot wire or rotating vane anemometers for determining the gas velocity exiting the openings. The weight of particulates/volume of sample air collected and the average velocity across the openings are combined with the measured area of the opening to calculate the emission rate of the source. Grab samples of gaseous emissions may be taken at the same time as the particulate samples and the emission rate calculated in the same manner. Size distribution of the particulates may also be obtained simultaneously from a variety of methods.

3.4.1 Sampling Equipment

Pollutants that may be measured by the roof monitor technique are limited to those that can be airborne sufficiently to exit the enclosure or structure through the vent openings, i.e., particulates and gases. The gross measurement requirements for survey sampling of particulates are best satisfied by high volume filter impaction devices to provide data on the average emission rate, particle size distribution, and particle composition. Particle charge transfer or piezoelectric mass monitoring devices may be utilized for continuous or semi-continuous sampling of intermittent emission sources where peak levels must be defined.

Gaseous emissions in survey programs are usually grab-sampled for laboratory analysis using any of a wide variety of evacuated sampling vessels. Continuous or semi-continuous sampling of specific gases may

be accomplished using such devices as, for example, continuous monitor flame ionization detectors (for hydrocarbons) and automated West-Gaeke bubblers/impingers (for sulfur dioxide). Figures 3-1 and 3-2 show typical setups utilized for roof monitor/ventilator sampling for fugitive emissions.

3.4.2 Sampling Systems Design

The number and location of devices used to collect samples are extremely important to the successful completion of a survey roof monitor sampling program, especially since the program is designed for minimum cost and provides for no replication of samples. The design of the sampling system is influenced by such factors as source complexity and size, physical location and size of the vent openings, variability of the mass rate and temperature of the emissions, as well as the homogeneity of the emissions. Most situations will, in general, fit into some combination of the following parameters:

Source - Sources may be either homogeneous, emitting a single type of mixture of pollutants from each and every emission location, or heterogeneous, emitting different types or mixtures of pollutants from different locations. The resultant pollutant emission "cloud" ("cloud" being used to describe the fugitive emission plume boundaries) from a homogeneous source will be homogeneous. The pollutant as a result of mixing by suitably directed or turbulent enclosure/structure air flow, homogeneous. The physical size of a source will determine the extent of the pollutant emission "cloud" and may influence its homogeneity. The proximity of sources within the enclosure/structure will also determine the extent of the "cloud" and its homogeneity.

Emission Character - The time duration of the emissions may limit the effective sampling time. Sources which have a short time cycle (<10-15 minutes) may require different sampling methods than those of a one-hour or more time scale. The temperatures of the emissions will also effect sampling. Excessive temperatures may limit the sampling time for the emissions. If temperatures cycle excessively, instrumentation which can quickly adjust to this cycle would be required.

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be accomplished using such devices as, for example, continuous monitor flame ionization detectors (for hydrocarbons) and automated West-Gaeke bubblers/impingers (for sulfur dioxide). Figures 3-1 and 3-2 show typical setups utilized for roof monitor/ventilator samplers for fugitive emissions.

3.4.2 Sampling Systems Design

The number and location of devices used to collect samples are extremely important to the successful completion of a survey roof monitor sampling program, especially since the program is designed for minimum cost and provides for no replication of samples. The design of the sampling system is influenced by such factors as source complexity and size, physical location and size of the vent openings, variability of the mass rate and temperature of the emissions, as well as the homogeneity of the emissions. Most situations will, in general, fit into some combination of the following parameters:

Source - Sources may be either homogeneous, emitting a single type of mixture of pollutants from each and every emission location, or heterogeneous, emitting different types or mixtures of pollutants from different locations. The resultant pollutant emission "cloud" ("cloud" being used to describe the fugitive emission plume boundaries) from a homogeneous source will be homogeneous. The pollutant as a result of mixing by suitably directed or turbulent enclosure/structure air flow, homogeneous. The physical size of a source will determine the extent of the pollutant emission "cloud" and may influence its homogeneity. The proximity of sources within the enclosure/structure will also determine the extent of the "cloud" and its homogeneity.

Emission Character - The time duration of the emissions may limit the effective sampling time. Sources which have a short time cycle (<10-15 minutes) may require different sampling methods than those of a one-hour or more time scale. The temperatures of the emissions will also effect sampling. Excessive temperatures may limit the sampling time for the emissions. If temperatures cycle excessively, instrumentation which can quickly adjust to this cycle would be required.

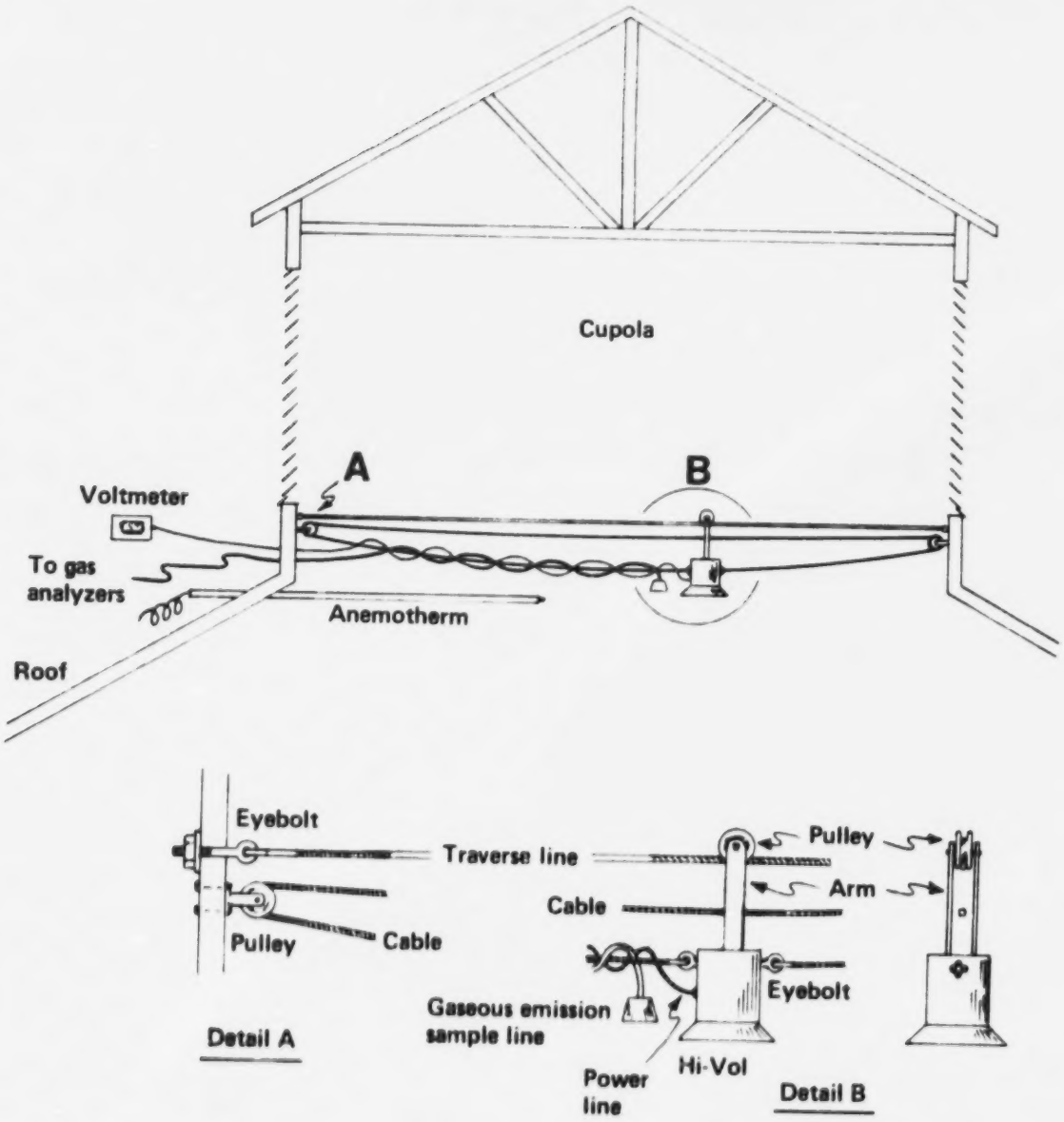


Fig. -1. Electric arc furnace operation; roof monitor showing sampling/mounting configuration.

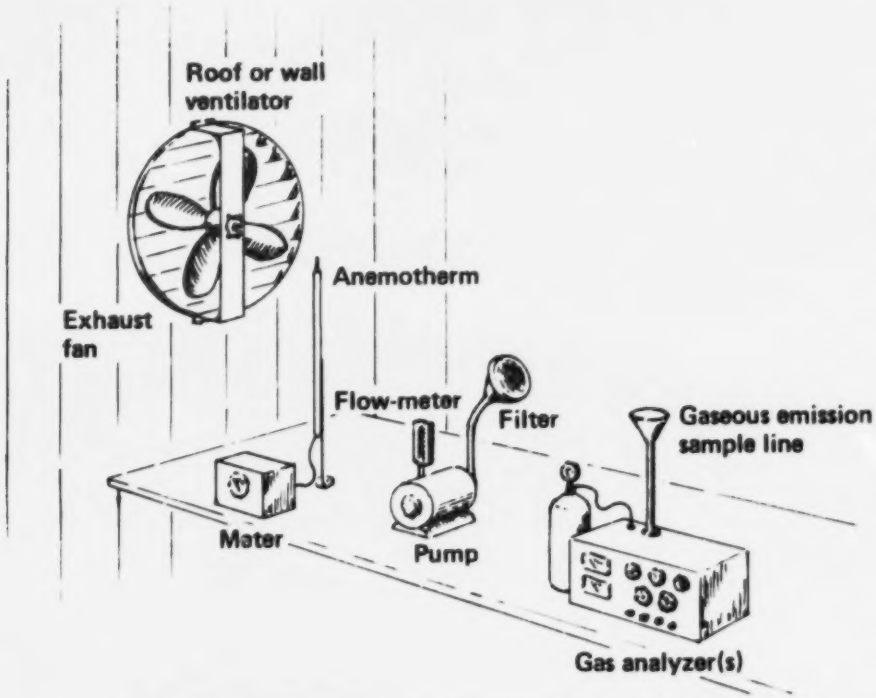


Fig. 3-2a. Roof or wall ventilator sampling configuration (with or without fan).

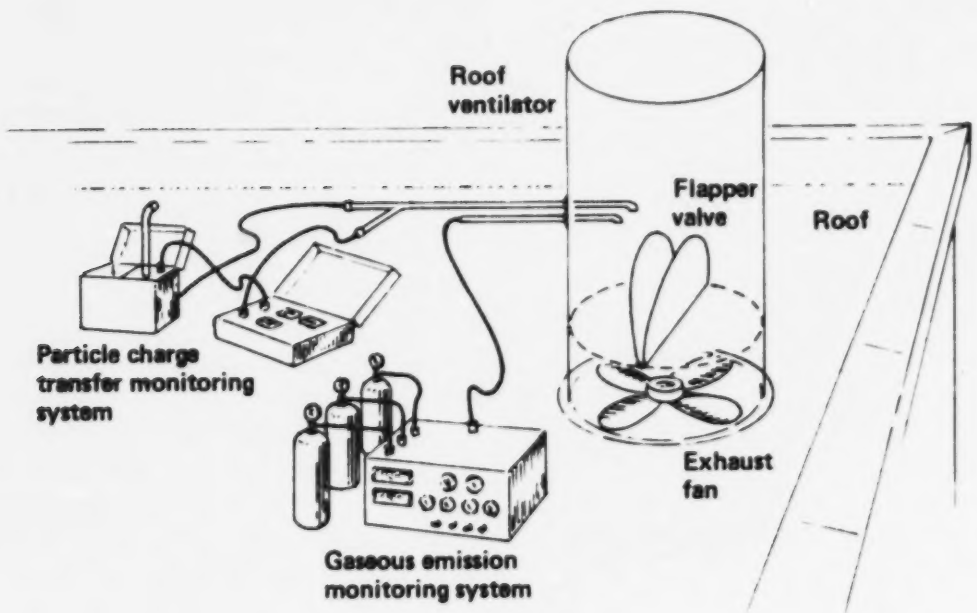


Fig. 3-2b. Roof ventilator sampling configuration.

Site Accessibility - If the site is not readily accessible, continuous monitoring equipment, which is usually higher in cost and also in complexity of arrays, might be required to measure the fugitive emissions. If standard hi-vols are used, extra samplers would need to be located in the roof monitor to conserve the number of times the sampling site has to be accessed to recover samples. Remote timing equipment and remote recording would be required also.

Emission Cycle - If the emission cycle is short, continuous monitoring equipment may be required. If not, multiple samples may need to be taken on the same filter. In this case, a remote timing and recording equipment would be required.

Table 3-3 outlines elements of conceptual systems for roof monitor sampling programs. These elements are keyed to the numbers on the Matrix of Table 3-2, and they correspond to the appropriate system elements needed to measure fugitive emissions for that matrix entry. Each matrix entry corresponds to a specific combination of factors which make up a particular roof monitor sampling program for a specific source.

3.4.3 Sampling Techniques

Sampling must be scheduled and carefully designed to ensure that data representative of the emission conditions of concern are obtained. Effective scheduling demands that sufficient knowledge of operations and process conditions be obtained to determine proper starting times and durations for samplings. The primary concern of the sampling design is that sufficient amounts of the various pollutants are collected to provide meaningful measurements.

Each of the various sample collection and analysis methods has an associated lower limit of detection, typically expressed in terms of micrograms of captured solid material and either micorgrams per cubic meter or parts per million in air of gases. Samples taken must provide at

TABLE 3-2

MATRIX OF POSSIBLE COMBINATIONS OF KEY TEST PARAMETERS

Combination Number	Source Homogeneity	Emissions Point Geometry	Site Accesibility	Emission Cycle	Suitable System Elements
1	Homogeneous	Simple	Easy	Short	(1),(4)
2	Homogeneous	Complex	Difficult	Long	(5)
3	Homogeneous	Simple	Difficult	Short	(4)
4	Homogeneous	Complex	Easy	Long	(3)
5	Homogeneous	Simple	Easy	Long	(1)
6	Homogeneous	Complex	Difficult	Short	(5)
7	Homogeneous	Simple	Difficult	Long	(1),(4)
8	Homogeneous	Complex	Easy	Short	(5)
9	Heterogeneous	Simple	Easy	Short	(4)
10	Heterogeneous	Complex	Difficult	Long	(6,)(5)
11	Heterogeneous	Simple	Difficult	Short	(4)
12	Heterogeneous	Complex	Easy	Long	(6),(5)
13	Heterogeneous	Simple	Easy	Long	(2)
14	Heterogeneous	Complex	Difficult	Short	(5)
15	Heterogeneous	Simple	Difficult	Long	(4)
16	Heterogeneous	Complex	Easy	Short	(5)

(1) . . . etc. Numbers refer to conceptual system elements for a roof monitor sampling program most suitable for a given matrix element, as described in Table 3-2.

TABLE 3-3

ELEMENTS OF CONCEPTUAL SYSTEMS FOR A ROOF MONITOR SAMPLING PROGRAM AS APPLIED TO SPECIFIC TYPES OF FUGITIVE EMISSION SOURCES*

1.	One Hi-Vol Sampler One Rotating Vane Anemometer One Cascade Impactor	Fixed Station In Monitor
2.	Two Hi-Vol Samplers Two Rotating Vane Anemometers Two Cascade Impactors	Fixed Station In Monitor
3.	One Hi-Vol Sampler One Rotating Vane Anemometer One Cascade Impactor	Fixed Station In Monitor
	One Portable Anemometer (Vane or Hot Wire One Respirable Dust Monitor	Manual Traverse of Doors & Windows
4.	One Continuous Particulate Monitor One Rotating Vane Anemometer One Cascade Impactor	Movable Across and Down Roof Monitor
5.	One Continuous Particulate Monitor One Rotating Vane Anemometer One Cascade Impactor	Movable Across and Down Roof Monitor
	One Portable Anemometer One Respirable Dust Monitor	Manual Traverse of Doors & Windows
6.	Two Hi-Vol Samplers Two Rotating Vane Anemometers Two Cascade Impactors	Fixed Station In Monitor
	One Portable Anemometer One Respirable Dust Monitor	Manual Traverse of Doors & Windows

*All gaseous sampling done using grab samples for laboratory analysis.

least these minimum amounts of the pollutants to be quantified. The mass (M) of a pollutant collected is the product of the concentration of the pollutant in the air (χ) and the volume of air sampled (V), thus,

M (micrograms) = χ (micrograms/cubic meter) x V (cubic meters).

To ensure that a sufficient amount of pollutant is collected, an adequately large volume of air must be passed through such samplers as particle filters or gas absorbing trains for a specific but uncontrollable concentration. The volume of air (V) is the product of its flow rate (F) and the sampling time (T), or,

V (cubic meters) = F (cubic meters/minute) x T (minutes).

Since the sampling time is most often dictated by the test conditions, the only control available to an experimenter is the sampling flow rate. A preliminary estimate of the required flow rate for any sampling location may be made if an estimate or rough measurement of the concentration expected is available. The substitution and rearrangement of terms in the above equations yields Equation 3-1:

F (cubic meters/minute) = M (micrograms/χ (micrograms/cubic meter) x T (minutes). (3-1)

This equation permits the calculation of the minimum acceptable flow rate for a required sample size. Flow rates should generally be adjusted upward by a factor of at least 1.5 to compensate for likely inaccuracies in estimates of concentration.

Grab samples of gaseous pollutants provide for no means of pollutant sample quantity control except in terms of the volume of the sample. Care should be taken, therefore, to correlate the sample size with the requirements of the selected analysis method.

The location of samplers is also important in obtaining representative data. Where the emissions are known to exit the roof monitor or vent in a homogeneous pollutant "cloud", one sampler can be used. However, where the pollutant "cloud" is not known to be homogeneous or is definitely heterogeneous, samplers should be located at 25-100 ft intervals.

In addition, unless approximations can be made based upon relative flowrates, a sampler must be located at each separate roof monitor or vent location on the building/enclosure. This can be simplified if inspection of the site indicates that some of these vents are only minor sources of the fugitive emissions.

A critical concern in development of the mass emission rates from roof monitor fugitive emission tests is the accuracy of the flow measurements required to change air quality measurements into mass emissions. The basic equation is:

Mass Rate (micrograms/minute) = M (micrograms)/T (minutes) =

χ (micrograms/cubic meter) x F (cubic meters/minute)

Where χ is known quite accurately, F is the overriding error limit for fugitive emissions measurements. F can be obtained from:

F (cubic meters/minute) = A (square meters) x U (meters/second)

Preliminary estimates of the linear velocity (V) can be obtained by use of a hand hot wire anemometer with a digital or scale readout. These will serve to determine what method of velocity measurement

TABLE 3-4

RANGE OF APPLICABILITY OF COMMON VELOCITY MEASUREMENT DEVICES FOR ROOF MONITOR SAMPLING

Device	Flow Range	Accuracy	Usable Temp. Range
Hot Wire Anemometer*	10-8000 fpm	Fair	0-225°F
Rotating Vane Anemometer	100-6000 fpm 50-6000 fpm	Fair at Low fpm Good at High fpm	0-150°F Mechanical 0-200°F Electric
Pitot Tube Calibrated	500-6000 fpm	Good	0-2000°F***
Magnehelic Gauge**	2000-10,000 fpm	Good	0-200°F

*Cannot be used for sources with significant steam or water content.

**Although accurate has very narrow range of flow measurement and must be calibrated for opening used.

***Water cooled for high temperatures.

will be the most accurate. Temperature readings should also be taken to determine the most suitable instrument. Table 3-4 summarizes data on the four instruments which would be most suitable, which are:

1. Hot Wire Anemometers
2. Rotating Vane Anemometers
3. Pitot Tubes
4. Magnehelic Gauges (after calibration)

The method chosen must take into account:

1. Compatibility with chosen sampling site conditions.
2. Compatibility with desired error limits of tests.

3.4.4 Data Reduction

When the sampling program has been completed and the samples have been analyzed to yield average pollutant concentrations in micrograms of particulate matter or parts per million of gases in the pollutant emission "cloud", the source strength must be calculated. As previously mentioned, this requires the multiplication of these values by the cross sectional area of the opening and the average linear velocity across that opening. This must be done for every significant roof monitor or vent in the building/enclosure studied to establish the process fugitive emission rate in grams per second, or other appropriate mass emission rate units.

3.5 Detailed Roof Monitor Sampling Strategy

A detailed measurement system is designed to more precisely identify and quantify specific pollutants that a survey measurement or equivalent data indicate as a possible problem area. A detailed system is necessarily more complex than a survey system in terms of equipment, system design,

sampling techniques and data reduction. It requires a much larger investment in terms of equipment time and manpower and yields data detailed and dependable enough for direct action towards achieving emission control.

Detailed systems in general employ sampling networks to measure the concentration and distribution of specific pollutants within the pollutant emission "cloud". The detailed measurements of pollutant distribution and emission rate variation replace the averaging techniques or the assumptions of representativeness of the sampling done in survey sampling systems. Detailed systems are frequently employed to compare the emissions at different process or operating conditions to determine which conditions dictate the need for emission control.

The data provided by the sampling network are processed in conjunction with detailed studies of the volumetric flow rate of the emissions from the roof monitor or vents to determine mass emission rates from the fugitive sources.

The complexity of a detailed system is largely determined by the basic accuracy desired; increasing accuracy demands more measurements either in the number of locations measured or in the number of measurements made at each location, or both. Most detailed systems will require a network of sets of instrumentation located across the plane of the opening to make simultaneous measurements since the usually lower concentrations of specific emissions preclude the use of traversing techniques with inherently short sampling durations, or assumptions regarding the distribution of emissions in the flow through the opening.

Identification and quantification of a specific fugitive emission from an enclosed source may involve measurements at more than one building opening if the flow through the separate openings is of comparable magnitude and the openings are situated to result in selectivity in the character or quantity of the emission being vented. This could occur, for example, when a roof monitor and a floor level door or window both vent emissions from a variety of sources within a building. Lighter gaseous emissions and smaller particulates would be expected to vent through the monitor, while the heavier gases and larger particulates would tend to settle and vent through the lower opening. If either of the openings is situated to vent all or most of the emissions from a specific source, resulting in a different type of emission for the two openings, the detailed measurement system might require different types of instrumentation at each location, thus adding to the system complexity.

3.5.1 Sampling Equipment

The pollutants to be characterized by a detailed roof monitor sampling system fall into the same two basic classes--airborne particulates and gases--as those measured by survey systems. Detailed sampling and analysis equipment is generally selected to obtain continuous or semi-continuous measurements of specific pollutants rather than grab-sampled overall measurement.

Particulate samples are collected using filter impaction, piezoelectric, and size selective or adhesive impaction techniques. Gases

are sampled and analyzed using flame ionization detectors, bubbler/impinger trains, non-dispersive infrared or ultraviolet monitors, flame photometry, and other techniques specific to individual gaseous pollutants.

The selection of suitable sampling equipment should be influenced by such considerations as portability, power requirements, detection limits and ease of control.

3.5.2 Sampling System Design

The basic criteria reviewed in Section 3.4.2 for the design of a survey sampling system are generally applicable to the design of a detailed system. The need for replacement of survey assumptions as to pollutant distribution with actual measured values, however, most frequently requires the design of a sampling network that will provide samples of a distribution at various distances along the width of the source in both the horizontal and vertical directions. Sampler locations may generally be determined in the same manner as those for a survey systems except that they must be capable of finer analysis of pollutant distribution. For detailed measurements, each location must make provision for sampling across the section of the pollutant emission "cloud" horizontally and/or vertically. Horizontal distributions over the length of the roof monitor may be measured by adding a number of samplers (usually at least two) at either side of the survey sampler location at distances estimated to yield significantly different pollutant concentrations. Vertical distributions as well as horizontal distributions across the width of the roof monitor are best determined by traversing with the samplers or their probe devices.

General rules which might be applied to system design are as follows:

1. If emissions are reasonably homogeneous, sampler locations along the horizontal length of the roof monitor should be 25-50 ft apart maximum. If heterogeneous, they should be 10-20 ft apart.

2. Vertical distances greater than 10-20 ft in roof monitor openings would require either vertically tiered samplers or traversing arrangements.

3. Traversing across the width of a roof monitor or setting up a network in that width can be employed to sample emissions before they leave the roof monitor. In cases where external accessibility is a problem, this can be used to obtain representative samples without leaving the building.

4. If any significant emissions (> 10%) are presumed to exit the enclosure/structure by other than the roof monitor, that vent or exit should have its own sampler system.

5. Where a minor (< 10%) amount of emissions are presumed to exit the enclosure/structure by other than the roof monitor, some estimate of this should be obtained using a portable and simplified sampler system (survey type). There can be many such openings and caution should be applied to avoid excess expenditure of time/money for tests of such minor sources.

3.5.3 Sampling Techniques

In order to obtain representative results of detailed quality, sampling techniques must:

1. Differentiate the peak emissions from the average fugitive emissions of a process. Online continuous readout devices are preferable in these cases.

2. Determine the horizontal and vertical distribution of pollutants within the emission "cloud". Multiple online continuous readout devices as well as traversing are preferable in these cases.

3. Differentiate specific components of the emissions, preferably those of highest hazard/toxicity to humans. Single component continuous online monitors or detailed laboratory analysis of collected samples of particulates, gases or liquids are preferred.

The specific techniques which might be employed vary. However, the selection criteria should include:

1. Portability
2. Power Requirements
3. Detection Limits
4. Response Time
5. Ease of Control (remote or close at hand)

3.5.4 Data Reduction/Data Analysis

After the analyses for pollutants are completed, the required calculations are made for emission concentrations, including calculations for the mean and standard deviation. Statistical differences between test methods can be obtained and confirmed by conducting various statistical significance procedures such as the "t" and "f" tests on the mean and standard deviation values for the various test methods. A tabulation of the statistical analysis results can then be made and related to the process conditions at the time of the tests. Finally, the investigator can determine whether there is a correlation between the emission results by test method and the process conditions.

3.6 Tracer Tests

Complex sources, consisting of several different sources with similar or very different emission rate patterns, can be the cause of the fugitive emissions from the roof monitor of a structure or enclosure. Emission measurements at the roof monitor of complex sources must be related back to a specific source to determine what is the most significant cause of figutive emissions. Tracers can be released at specific rates at the location of the source to be studies for specific time periods. Knowledge of this,

as well as what sampler caught this tracer and in what concentration, can serve to differentiate each source's contribution to the fugitive emissions.

3.6.1 Tracers and Samplers

Both particulate and gaseous atmospheric tracers are in general use. The most commonly used particulate tracers are zinc sulfide and sodium fluorescein (uranine dye). The primary gaseous tracer is sulfur hexafluoride (SF_6).

Zinc sulfide is a particulate material which can be obtained in narrow size ranges to closely match the size of the pollutant of concern. The material is best introduced into the atmosphere in dry form by a blower type disseminator although it can be accomplished by spraying from an aqueous slurry solution. The zinc sulfide fluoresces a distinctive color under ultraviolet light which provides a specific and rapid means of identification and quantification of the tracer in the samples.

Sodium fluorescein is a soluble fluorescing particulate material. It is normally spray disseminated from an aqueous slurry solution to produce a particulate airborne plume, the size distribution of which can be predetermined by the spraying apparatus. Sodium fluorescein can be uniquely identified by colorimeter assessment.

Sulfur hexafluoride is a gas which can be readily obtained in ordinary gas cylinders. Sulfur hexafluoride can be disseminated by metering directly from the gas cylinder through a flow meter to the atmosphere. The amount disseminated can be determined by careful flow metering and/or weight differentiation of the gas cylinder.

Particulate tracers are usually sampled with filter impaction devices or, for particles over 10 microns in diameter, the more easily used and somewhat less accurate Rotorod sampler which collects particles on an adhesive-coated U- or H-shaped rod which is rotated in the ambient air by a battery-driven electric motor.

Sulfur hexafluoride gaseous samples are collected for laboratory gas chromatograph analysis in non-reactive bags of such materials as Mylar.

3.6.2 Tracer Sampling System Design

All of the design guidelines presented in 3.4.2 and 3.5.2 may be applied to the design of a tracer sampling system as site conditions dictate. Their application is, in general, simplified since the source strength may be controlled to provide measurable tracer concentrations at readily accessible sampling locations.

A single ambient sampler will usually be sufficient to establish that no significant amount of the tracer material is present in the ambient atmosphere approaching the source, enclosure or structure.

3.6.3 Tracer Sampling and Data Analysis

The methods introduced in Sections 3.4.3 and 3.5.3 for determining sampler design and location are fully applicable to tracer sampling. Like design guidelines, they may be more easily applied because of the control of source strength available.

The analysis of the data is also simplified since the source strength is known and no back-calculation is required.

3.7 Quality Assurance

The basic reason for quality assurance on a measurement program is to insure that the validity of the data collected can be verified. This requires that a quality assurance program be an integral part of the measurement program from beginning to end. This section outlines the quality assurance requirements of a sampling program in terms of several basic criteria points. The criteria are listed below with a brief explanation of the requirements in each area. Not all of the criteria will be applicable in all fugitive emission measurement cases.

1. Introduction

   Describe the project organization, giving details of the lines of management and quality assurance responsibility.

2. Quality Assurance Program

   Describe the objective and scope of the quality assurance program.

3. Design Control

   Document regulatory design requirements and standards applicable to the measurement program as procedures and specifications.

4. Procurement Document Control

   Verify that all regulatory and program design specifications accompany procurement documents (such as purchase orders).

5. Instructions, Procedures, Drawings

   Prescribe all activities that affect the quality of the work performed by written procedures. These procedures must include acceptance criteria for determining that these activities are accomplished.

6. Document Control

   Ensure that the writing, issuance, and revision of procedures which prescribe measurement program activities affecting quality are documented and that these procedures are distributed to and used at the location where the measurement program is carried out.

7. Control of Purchase Material, Equipment, and Services

Establish procedures to ensure that purchased material conforms to the procurement specifications and provide verification of conformance.

8. Identification and Control of Materials, Parts, and Components

Uniquely identify all materials, parts, and components that significantly contribute to program quality for traceability and to prevent the use of incorrect or defective materials, parts, or components.

9. Control of Special Processes

Ensure that special processes are controlled and accomplished by qualified personnel using qualified procedures.

10. Inspection

Perform periodic inspections where necessary on activities affecting the quality of work. These inspections must be organized and conducted to assure detailed acceptability of program conponents.

11. Test Control

Specify all testing required to demonstrate that applicable systems and components perform satisfactorily. Specify that the testing done and documented according to written procedures, by qualified personnel, with adequate test equipment according to acceptance criteria.

12. Control of Measuring and Test Equipment

Ensure that all testing equipment is controlled to avoid unauthorized use and that test equipment is calibrated and adjusted at stated frequencies. An inventory of all test equipment must be maintained and each piece of test equipment labeled with the date of calibration and date of next calibration.

13. Handling, Storage, and Shipping

Ensure that equipment and material receiving, handling, storage, and shipping follow manufacturer's recommendations to prevent damage and deterioration. Verification and documentation that established procedures are followed is required.

14. Inspection, Test, and Operating Status

Label all equipment subject to required inspections and tests so that the status of inspection and test is readily apparent. Maintain an inventory of such inspections and operating status.

15. Non-conforming Parts and Materials

Establish a system that will prevent the inadvertent use of equipment or materials that do not conform to requirements.

16. Corrective Action

Establish a system to ensure that conditions adversely affecting the quality of program operations are identified, corrected, and commented on; and that preventive actions are taken to preclude recurrence.

17. Quality Assurance Records

Maintain program records necessary to provide proof of accomplishment of quality affecting activities of the measurement program. Records include operating logs, test and inspection results, and personnel qualifications.

18. Audits

Conduct audits to evaluate the effectiveness of the measurement program and quality assurance program to assure that performance criteria are being met.

4.0 ESTIMATED CCSTS AND TIME REQUIREMENTS

Table 4-1 presents a listing of the conditions assumed for estimating the costs and time requirements of roof monitoring fugitive emissions sampling programs using the methodology described in this document. Four programs are listed, representing minimum and more typical levels of effort for each of the survey and detailed programs defined in Sections 3.4 and 3.5, respectively. The combinations of conditions for each program are generally representative of ideal cases for each level and may not be encountered in actual practice. They do, however, illustrate the range of effort and costs that may be expected in the application of the roof monitor technique.

4.1 Manpower

Table 4-2 presents estimates of manpower requirements for each of the sampling programs listed in Table 4-1. Man-hours for each of the three general levels of Senior Engineer/Scientist, Engineer/Scientist, and Junior Engineer/Scientist are estimated for the general task areas outlined in this document and for additional separable tasks. Clerical man-hours are estimated as a total for each program. Total man-hour requirements are approximately 400 man-hours for minimum effort and 750 man-hours for typical effort in survey programs , and 1600 man-hours for minimum effort and 2800 man-hours for typical effort in detailed programs.

4.2 Other Direct Costs

Table 4-3 estimates for equipment purchases, rentals, calibration, and repairs; on-site construction of towers and platforms; shipping and

TABLE 4-1

CONDITIONS ASSUMED FOR ESTIMATING COSTS AND TIME REQUIREMENTS FOR ROOF MONITOR FUGITIVE EMISSIONS SAMPLING PROGRAMS

Parameter	Survey Programs		Detailed Programs	
	Minimum Effort	Typical Effort	Minimum Effort	Typical Effort
Building Openings	1 Roof (Small)	1 Roof (Large)	1 Roof (Large)	1 Roof, 1 Window
Emissions Schedule	Constant	Cyclic	Constant	Cyclic, Mixed
Air Flow At Opening	Steady	Cyclic	Steady	Cyclic
Sampling Locations	1 Traverse	4 Fixed	4 Fixed	12/Opening Fixed
Sampling Frequency	Once	Once	4 Times	10 Times
Estimated Basic Accuracy	± 400%	± 150%	± 50%	± 20%

Small ~ 50' long monitor
Large ~ 200' long monitor

TABLE 4-2

ESTIMATED MANPOWER REQUIRIMENTS FOR ROOF MONITOR
FUGITIVE EMISSIONS SAMPLING PROGRAMS

Estimates in Man-Hours

Task	Survey Programs						Detailed Programs					
	Minimum Effort			Typical Effort			Minimum Effort			Typical Effort		
	Senior Engr/Sci	Engr/ Sci	Junior Engr/ Tech	Senior Engr/Sci	Engr/ Sci	Junior Engr/ Tech	Senior Engr/Sci	Engr/ Sci	Junior Engr/ Tech	Senior Engr/Sci	Engr/ Sci	Junior Engr/ Tech
Pretest Survey	4	8	0	4	8	0	8	16	0	12	24	0
Test Plan Preparation	4	12	0	4	12	0	8	24	0	12	32	24
Equipment Acquisition	0	0	12	0	8	20	0	16	40	0	16	80
Field Set-Up	0	16	24	8	64	30	8	64	40	24	128	128
Field Study	20	40	40	40	80	80	120	240	240	240	480	480
Sample Analysis	0	20	40	0	20	80	4	40	160	16	80	200
Data Analysis	0	20	40	8	20	80	16	40	160	32	80	200
Report Preparation	12	32	24	24	72	40	44	100	64	80	200	120
Totals	40	148	180	88	284	332	204	540	704	416	1040	1232
Engineer/Scientist Total		368			704			1448			2688	
Clerical		40			60			120			180	
Grand Total		408			764			1568			2868	

TABLE 4-3

ESTIMATED COSTS OTHER THAN MANPOWER FOR ROOF MONITOR
FUGITIVE EMISSIONS SAMPLING PROGRAMS

	Survey Programs		Detailed Programs	
Cost Item	Minimum Effort	Typical Effort	Minimum Effort	Typical Effort
Equipment				
Instrument Purchase	$1000	$2000	$3000	$12000
Calibration	50	100	200	800
Repairs	100	150	250	600
Platforms, Etc., Construction	200	500	600	3000
Shipping	200	400	500	800
Vehicle Rentals	200	500	800	1200
Communications	50	100	200	600
Miscellaneous Field Costs	50	100	200	800
TOTAL	$1850	$3850	$5750	$19800

on-site communications for each of the listed programs. Total costs are approximately $1,900 for minimum effort and $3,900 for typical effort in survey programs and $5,800 for minimum effort and $20,000 for typical effort in detailed programs.

4.3 Elapsed-Time Requirements

Figure 4-1 presents elapsed-time estimates for each of the listed programs broken down into the task areas indicated in the manpower estimates of Table 4-2. Total program durations are approximately 12 weeks for minimum effort and 19 weeks for typical effort in survey programs and 22 weeks for minimum effort and 33 weeks for typical effort in detailed programs.

4.4 Cost Effectiveness

Figure 4-2 presents curves of the estimated cost effectiveness of the roof monitor technique, drawn through points calculated for the four listed programs. Costs for each program were calculated at $30 per labor hour, $40 per man day subsistence for field work for the manpower estimates of Table 4-2, plus the other direct costs estimated in Table 4-3.

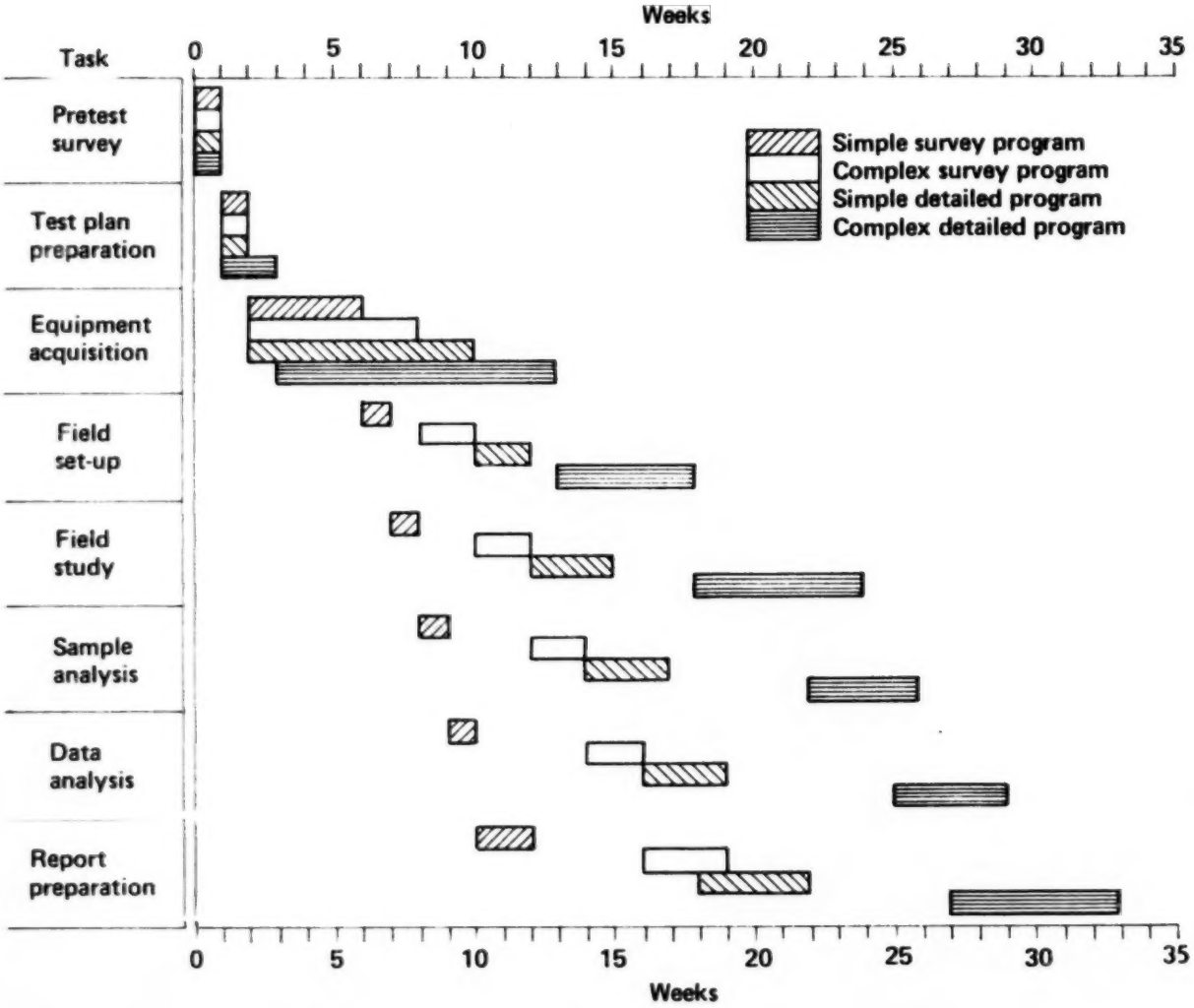


Fig. 4-1. Elapsed-time estimates for roof monitor fugitive emissions sampling programs.

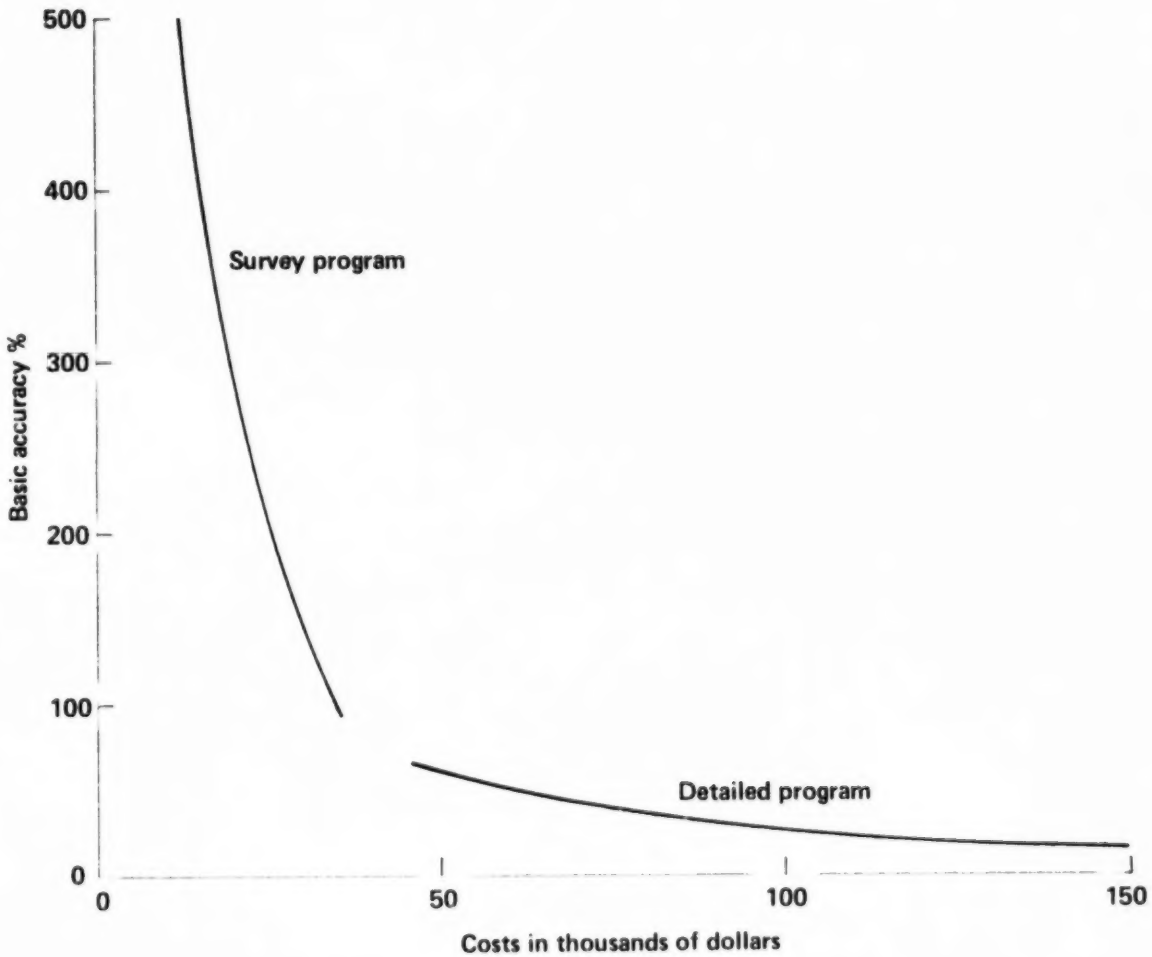


Fig. 4-2. Cost-effectiveness of roof monitor fugitive emissions sampling programs.

APPENDIX A

APPLICATION OF THE ROOF MONITORING SAMPLING METHOD TO AN ELECTRICAL ARC FURNACE INSTALLATION

A.1.0 INTRODUCTION

This appendix presents an application of the roof monitor fugitive emissions measurement system selection and design criteria to an electric furnace steelmaking shop. The criteria for the selection of the method and the design procedures for both survey and detailed sampling systems as presented in Sections 3.4 and 3.5 of this document are discussed.

A.2.0 BACKGROUND INFORMATION

The following information relative to the operation of an electric arc furnace was utilized to determine the sources and expected types of fugitive emissions that might be encountered in the measurement programs. Figure A-1 describes the use of the electric furnace in steelmaking and shows potential emission sources.

Sources of emissions at a typical electric arc furnace installation could include:

- o Charging of scrap to the hot furnace.
- o Leaks of hooding and/or electrode holes during melting.
- o Normal emissions from scrap melting.
- o Charging of limestone and flux to the melt.
- o Charging of alloying elements to the melt.
- o Tapping and pouring hot metal to the ladle.
- o Tapping and pouring slag into the slag ladle.
- o Transfer of hot metal within the electric furnace shop.

Both gaseous (CO, H_2S, SO_2, etc.) and particulate (iron, limestone, carbon, etc.) emissions are given off by these emission sources and would require quantification in any fugitive emission test program. Emissions from each of these sources can be potentially controlled by collection in a variety of hoods as illustrated in Figures A-2 and A-3, and transfer through ductwork to a remotely located baghouse. A typical state-of-the-art ventilation system for a three furnace shop is

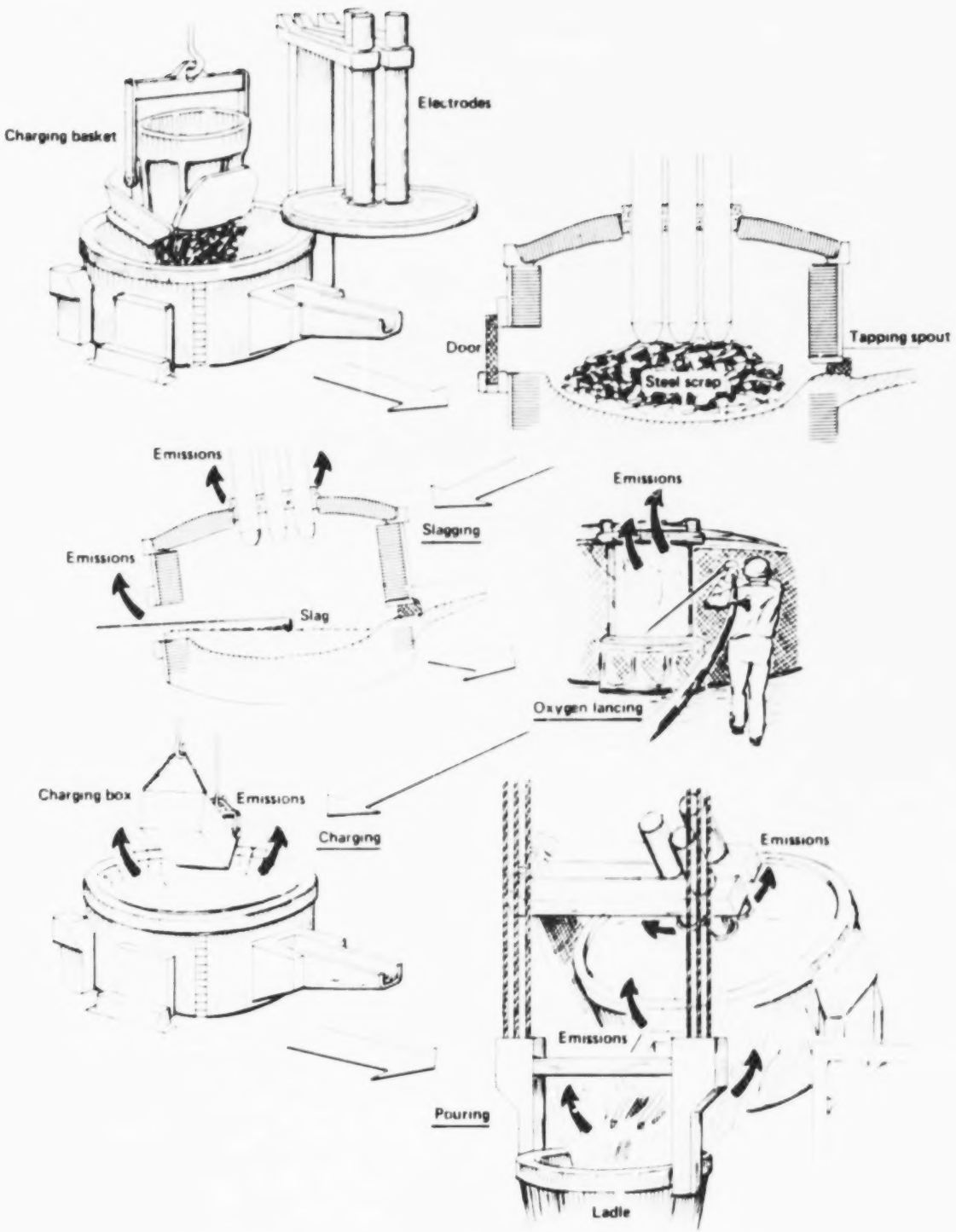


Fig. A-1 **Fugitive emissions in electric furnace steel making.**

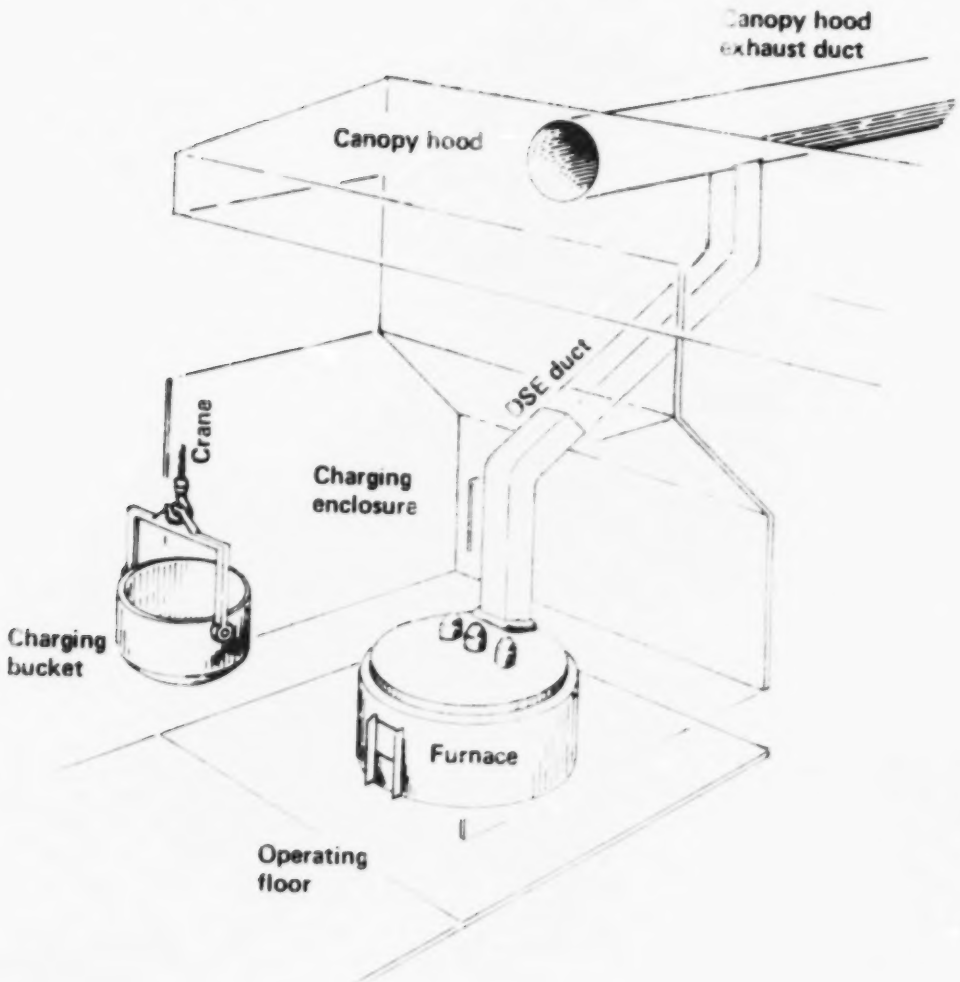


Fig. 4-2 Electric arc furnace-capture system for emissions.

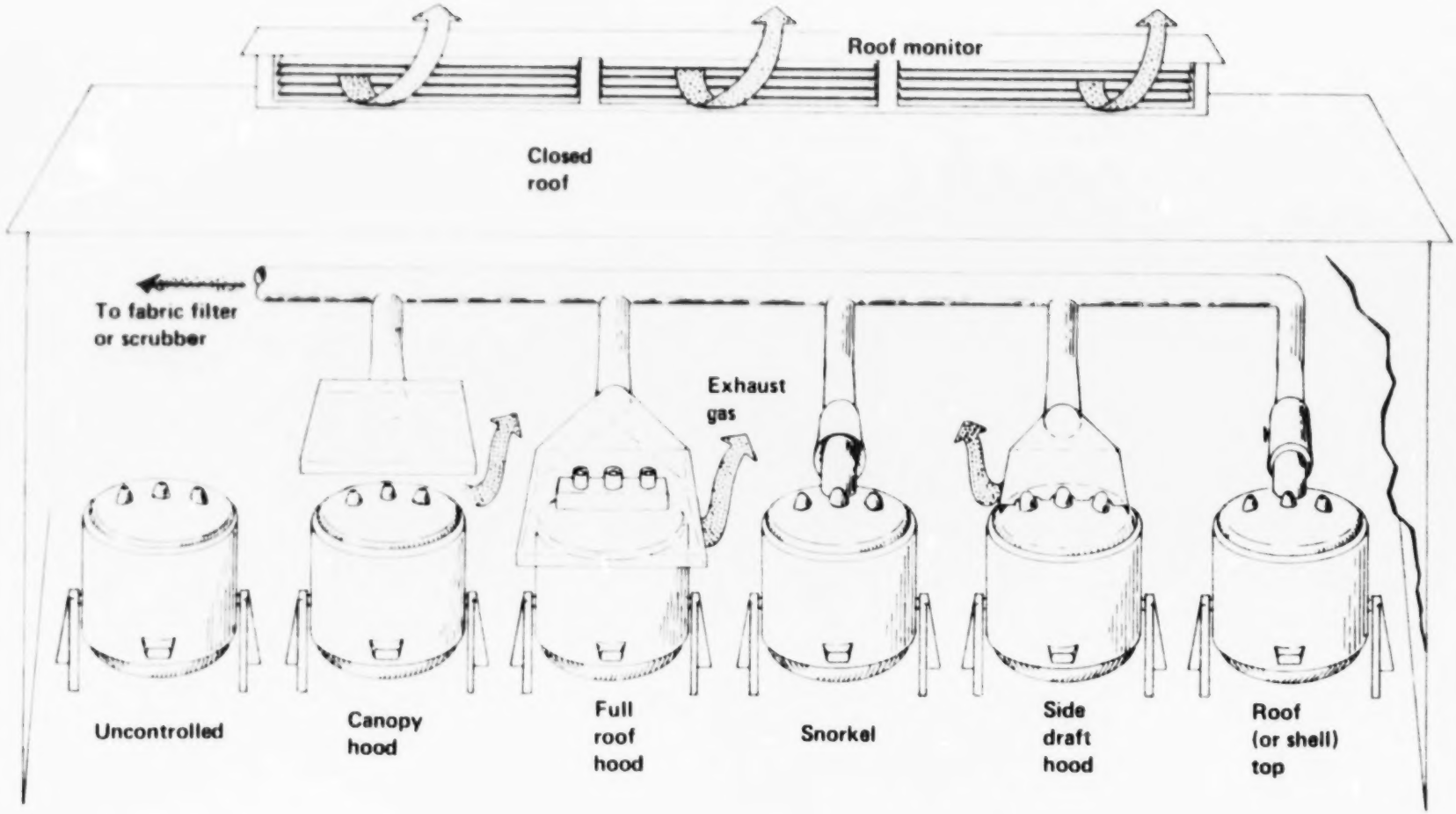
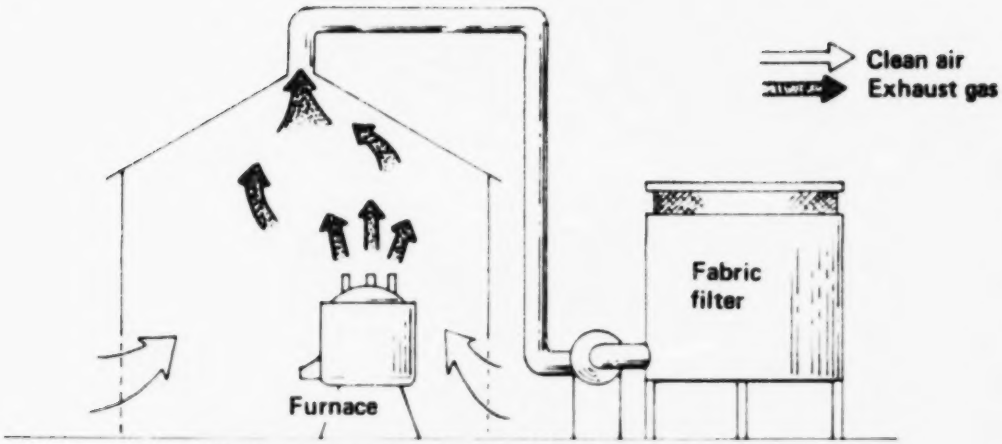


Fig. A-3 Electric arc furnace-fugitive emission control.

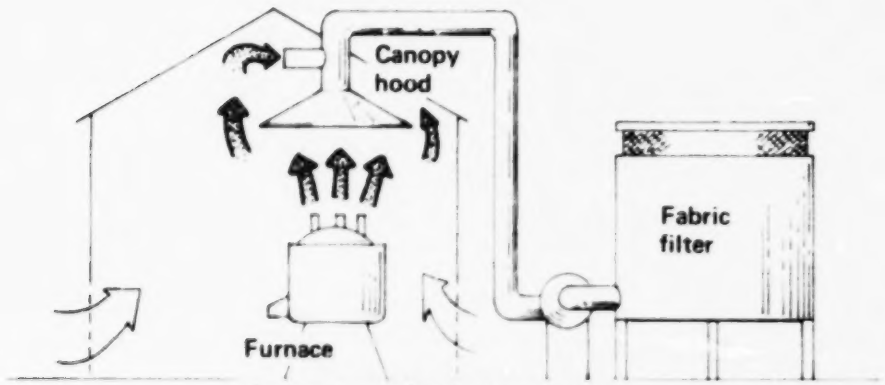
sketched in Figure A-4. These captured emissions can be readily identified and quantified utilizing duct-type sampling systems and methods.

Some portion of the emission from each source, however, escapes collection by the ventilation system and is carried out of the building via a roof monitor. These emissions are predominately those which occur when the furnace roof is removed and therefore the directly connected duct system must swing away either with or independent of the roof. Charging emissions are of that type, and latest designs for electric furnace shops use canopy hoods to reduce the released emissions which escape into the general shop areas. These uncaptured charging emissions are the most significant source of fugitive emissions from electric furnace steelmaking. Tapping and pouring emissions as well as hot metal transfer and transport emissions should not be ignored in the pre-test survey. Visual observation of the emission sources can aid in evaluating their significance as fugitive sources.

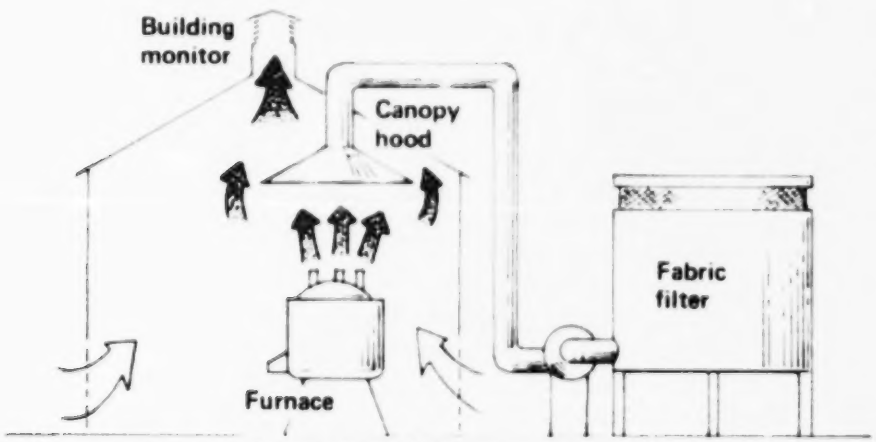
The EPA estimates for uncontrolled emissions, as published in the Office of Air Programs Publication AP-42, Compilation of Air Pollutant Emission Factors, are 9.2 lbs/ton metal charged without oxygen lance and 11 lbs/ton metal with oxygen lancing. Assuming 90 percent of the emissions are captured by control equipment, 0.9 to 1.1 lbs/ton metal charged could be transmitted to the atmosphere as fugitive emissions. The potential fugitive emissions from the roof monitor of a four furnace steelmaking operation with 100 ton capacity furnaces operating a three shift 24 hour cycle with 4 melts/day/furnace would therefore be 1,440 - 1,760 lbs/day of particulates, plus significant amounts of carbon monoxide, sulfur gases and other emissions.



Building evacuation (BE) system, closed roof.



Canopy hood (CH), closed roof.



Canopy hood (CH), open roof.

Fig. A-4 Electric arc furnace-charging/tapping fugitive emission control.

A.3.0 SURVEY MEASUREMENT SYSTEM

To determine the total plant contribution of particulates to the atmosphere, measurement must be made of the emissions from the roof monitor over a typical melt cycle from a single furnace. The results of this test can be extrapolated to estimate the total emissions over a 24 hour cycle of the entire electric furnace shop. Visual observations can aid in selection of the roof monitor location to ensure representativeness of the particulate emissions collected.

A.4.0 SAMPLER LOCATION

A typical sampler location is shown in Figure A-5. By visual observation within and outside the electric furnace shop a location which is within the "cloud" of fugitive emissions from a specific furnace can also aid in answering the questions:

- Is the particulate emission rate (as measured by opacity) of that furnace typical of the entire group of furnaces?
- Is the sampler location in the main flow path of the particulate "cloud"?
- How does the variance of particulate emissions with time affect the sampler location?
- How long a sampling period is required to obtain a representative melt cycle's particulate emissions?

A fixed location high-volume type of particulate sampler similar to that shown in Figure 3-1 would be used with a recording anemometer. The average flow rate of air through the roof monitor opening may be calculated as:

$$F = A \int_0^T \frac{dV}{T}$$

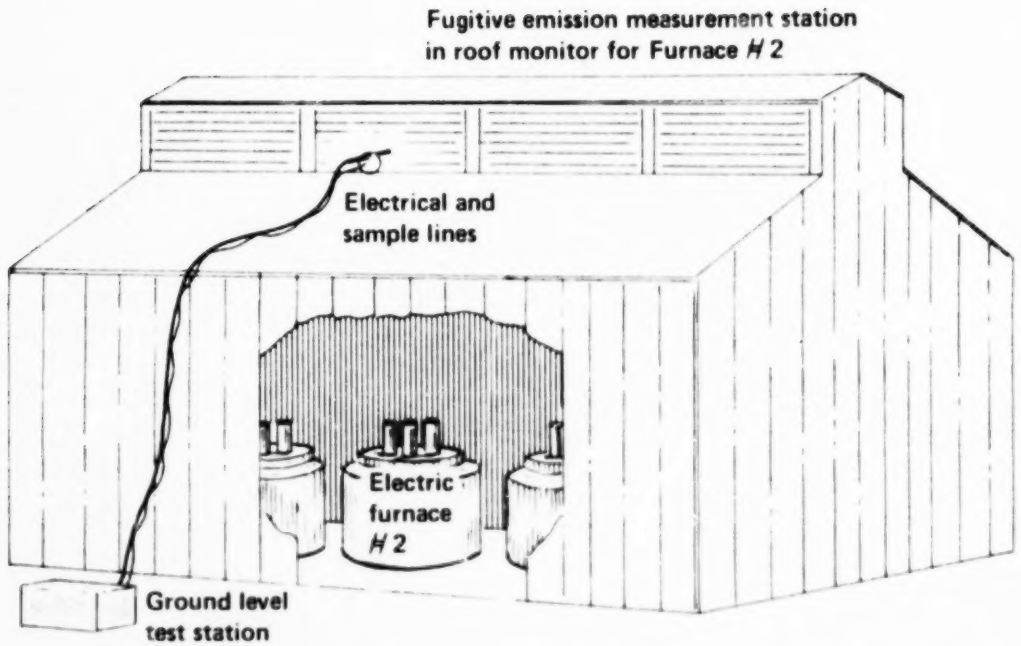
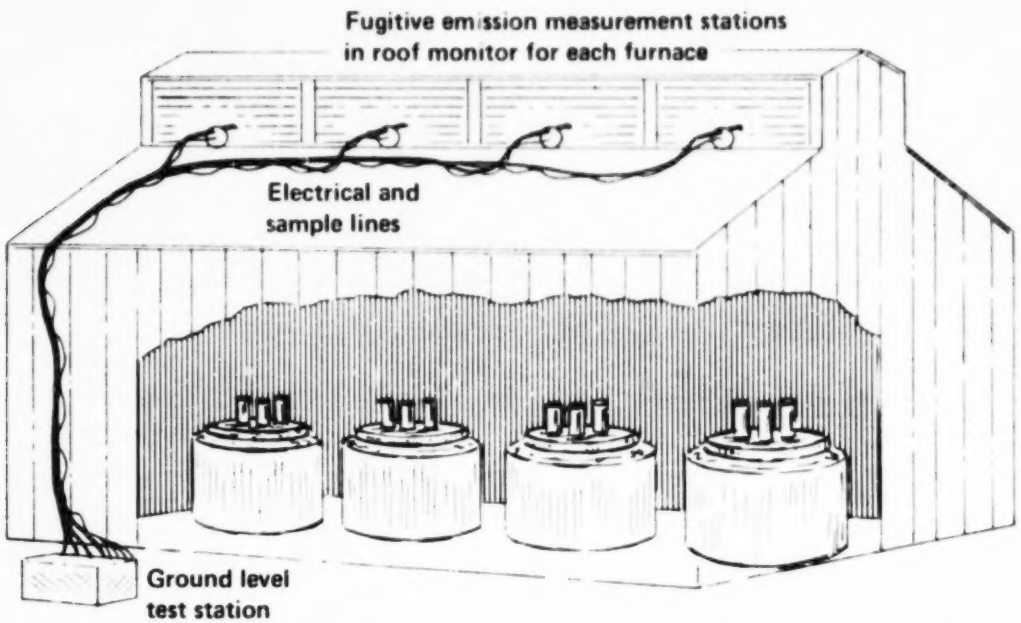


Fig. A- 5. Typical survey program site to determine the fugitive emissions from an electric furnace shop using a roof monitor technique.



F A-6 Typical detailed program site to determine the fugitive emissions from an electric furnace shop using a roof monitor technique.

where F = average air volume flow rate, cubic meters/minute

V = air velocity, meters/minute

A = roof monitor open area, square meters

τ = test duration, minutes.

V, A and τ are all directly measured values.

The particulate matter collected must be sufficient for measurement. For a high volume sampler of 18 cubic feet per minute, a desired sample weight would be 100 micrograms with a 60 minute minimum sampling time. The required concentration of particulate in the existing air would, therefore, be:

$$\chi = 10^{-4} \text{ (gm)}/0.5 \text{ (m}^3\text{/min)} \times 60 \text{ (minutes)}$$

$$\chi = 3.3 \times 10^{-6} \text{ (gm/m}^3\text{)}$$

This would be readily achieved if the particulate plume had a 10% or greater opacity.

Samples are therefore taken over a one hour or larger period and the volume of air passes through the sampler determined. Multiplication of the collected mass, by the average air flow through the roof monitor divided by the air flow through the sampler divided by the time period will give an estimate of the average emission rate in mass/time period for the total electric furnace shop in that time period. Section 3.4.3 details the calculations and how to estimate the sampling time periods.

A.5.0 DETAILED MEASUREMENT SYSTEM

To determine the total electric furnace shop emissions with some accuracy, measurements across the roof monitor of the emissions from all

of the furnaces. Figure A-6 shows such a setup for the roof monitor of a four furnace electric furnace shop. The samplers are similar to those shown in Figure 3-1. In addition, if canopy hoods are used to capture some charging and tapping emissions, they may be sampled by use of a set-up such as shown in Figure A-7.

The roof monitor sampling system must be designed to identify and quantify the electric arc furnace installation fugitive emissions by accurately measuring the air flow rate through the roof monitor while collecting samples of the emissions. The air flow rate will be determined by measuring the velocity of the air at a number of locations across the vertical plane of the monitor opening using hot-wire or rotating vane anemometers.

Sampling instruments for the measurement of the emissions will require at a minimum analyses for:

- o Carbon monoxide
- o Total suspended particulates
- o Particulate size distribution

Preferable analysis methods are:

Carbon monoxide -	non-dispersive infrared
Total particulates -	Hi-Vol or Fiberglas filters plus particulate charge count mass monitor
Particulate distribution -	Andersen Samplers or equivalent

The specific operations whose individual contributions to the total electric furnace shop fugitive emissions which can be differentiated include:

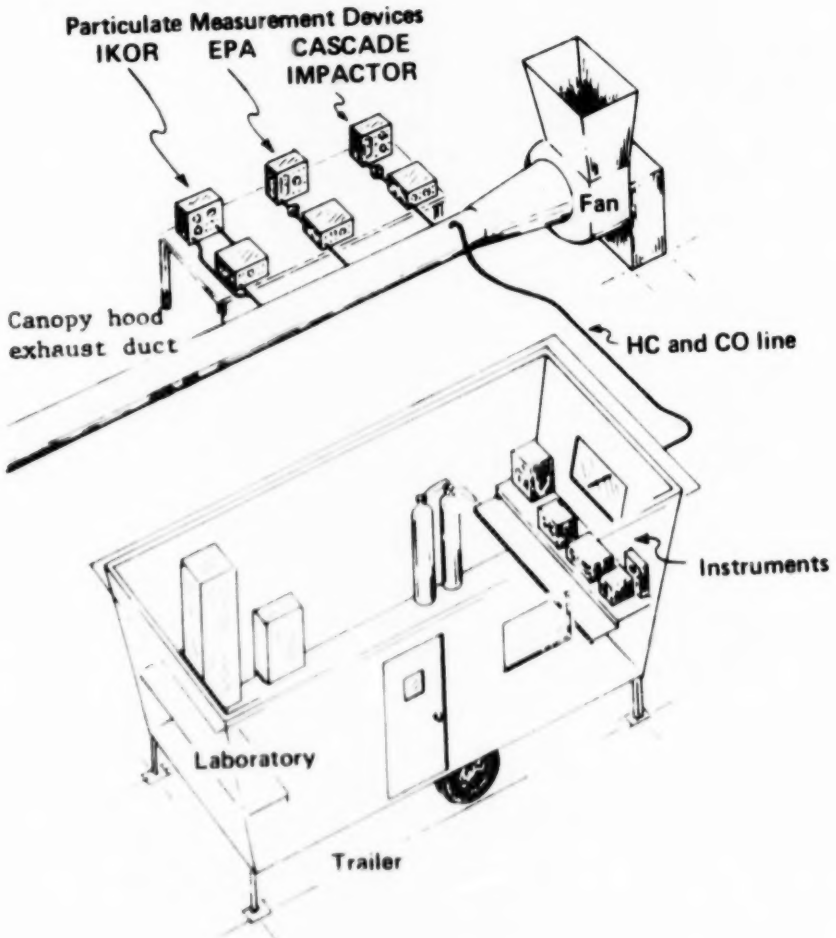


Fig. A-7. Illustration of test set-up for measuring fugitive emissions from an electric arc furnace canopy hood.

- o Charging of the hot furnace
- o Melting operations
- o Tapping and pouring

The use of continuous monitoring instrumentation permits the correlation of emission rate with the process operation to which it belongs. By monitoring the emissions for extended periods of time, meaningful average as well as instantaneous individual emission rates can thereby be obtained. Calibration of continuous traces with known concentration standards, both gaseous and particulate, is required to do this effectively.

A program designed to do this would include:

- o Continuous monitoring on a 24 hour basis of particulates and gases
- o Collection of filterable particulate matter after each total melt cycle in the furnace below each sampler
- o Continuous recording of anemometer traces on a 24 hour basis
- o Daily calibration of continuous monitors by comparison against reference standards. Calibration gases would be used for gaseous monitors and the high volume filter catch and that of the backup filter in the particle charge count mass monitor for particulate monitors.

Additional data on the emission rates of certain specific pollutants could also be obtained by use of:

- o Flame photometer continuous monitoring of sulfur gases
- o EPA Method 5 trains with condensible trains and organic emission absorber tubes to batch analyze for organics, especially carcinogens
- o Membrane type filters for collection and batch chemical/morphological analysis of specific inorganic particulate constituents such as toxic metals and free silica.

These should be at the discretion of the investigator, since they contribute more than their proportionate share to the manpower time and money investment in the fugitive emission sampling program.

A typical 4-6 week program would involve 24 hour tests on a four furnace shop, thus potentially acquiring 24 total melt cycles/day or 480 to 720 sets of data. Because of potential problems of equipment breakdown in the hot and dirty environment in which they are used, as well as the use of a 12 hour test shift (to allow use of a single well trained test crew) gives us a potential of 120 to 180 actual data sets. Each can be broken down into subsets of:

- Furnace tested
- Type and amount of charge used
- Type and amount of fluxes and/or additives used
- Portion of operating cycle involved (charge, melt, pour)
- Data reliability and completeness

Emission factors for each part of the electric furnace melt cycle can be determined in addition to the average emission rate as determined for the survey test program. We can break down the collected mass of particulate and the flow rate as follows:

F_1 = flow rate for charge part of cycle
M_1 = mass collected for charge part of cycle

F_2 = flow rate for melt part of cycle
M_2 = mass collected for melt part of cycle

F_3 = flow rate for tap/pour part of cycle
M_3 = mass collected for tap/pour part of cycle

The on-line mass monitors will be required for this. Calculations can be done as in Section 3.4.3 of each individual mass rate of emission of particulates from parts of the cycle. Similar analysis can be done for the gaseous emissions when continuous monitors are used. The result of this program would be very detailed knowledge of the fugitive emissions from a typical electric furnace melt cycle.

An additional tool to be used where better definition of exact emission sources and rates is needed is the use of in-plant tracers to simulate the sources. Gases such as SF_6 (sulfur hexaflouride) or (florescent dye particulates) can be released at specific points and at measured rates inside the electric furnace shop to simulate fugitive sources. These tracers are collected at the roof monitor and from the collection efficiency and concentration of collected tracer, a more accurate picture of fugitive source locations and mass rates can be determined.